Study on the Collimated Jets of Comet 19P/Borrelly

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Planetary Data Systems: Small Bodies Node

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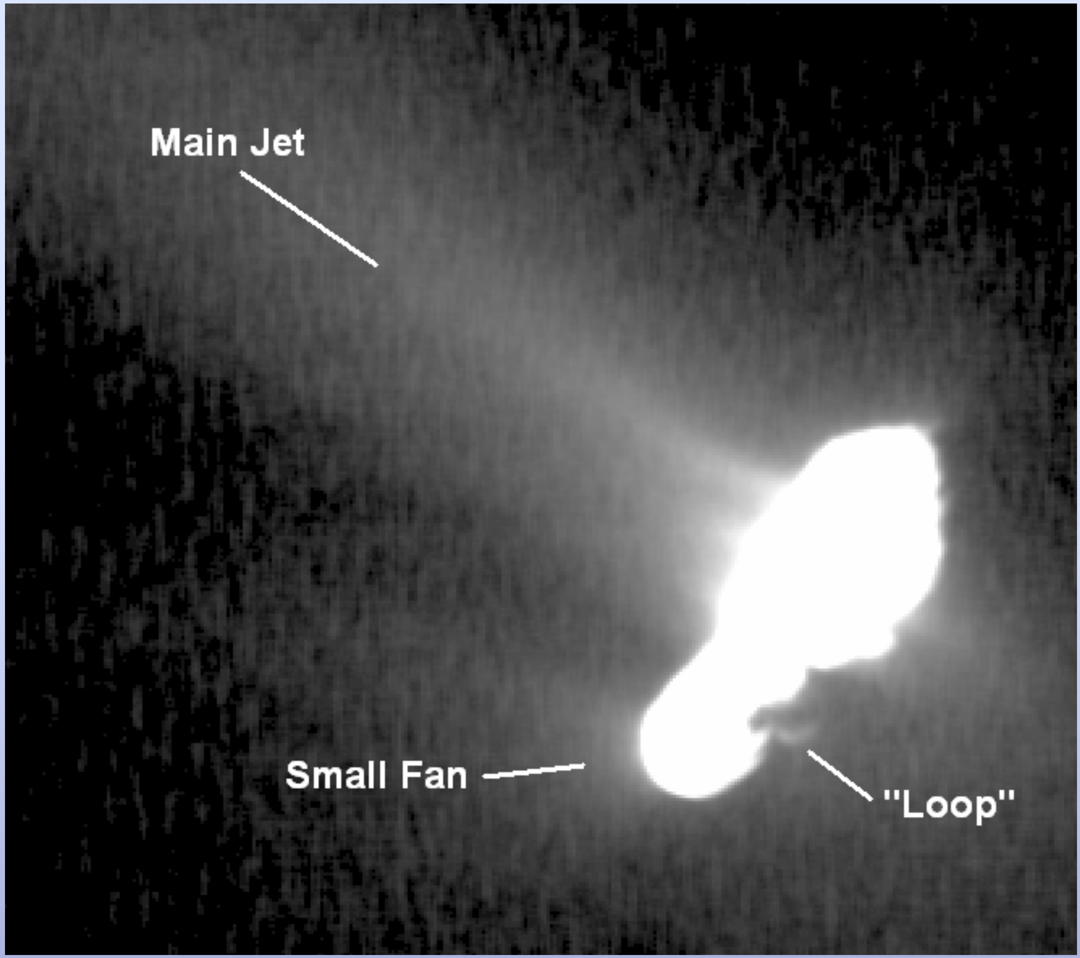
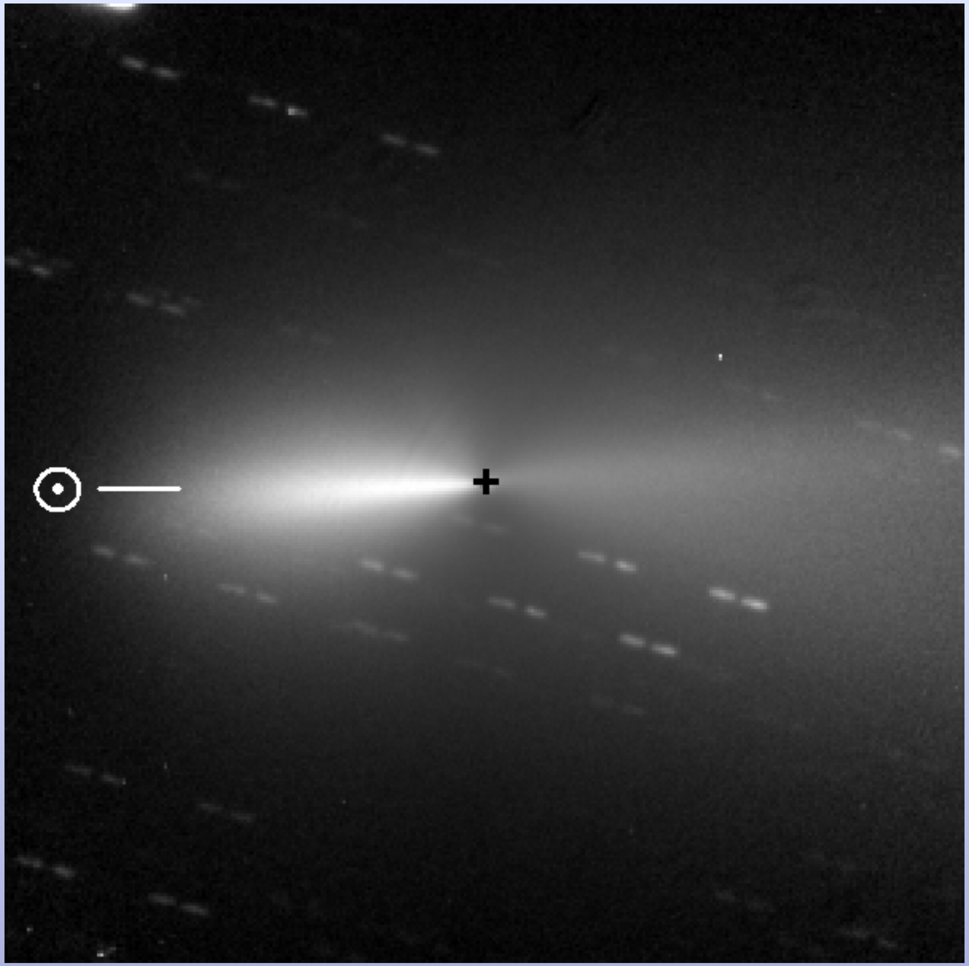
Comet 19P/Borrelly



DS1 MICAS Image taken from a range of 4825 km, at a resolution of 63 m pixel^{-1}, and a phase angle of 62.5°

Ground Based Observations



The long jet of material clearly shows collimation, with hemispherical distribution of gas
range: 50,000 km

Background Research

- Deep Space 1
  - Validate high-risk technologies that are important for future missions
  - Obtain images and spectra of the near-Earth asteroid 9969 Braille (1999 K2) and the comet 19P/Borrelly
  - September 22, 2001 at 22:30 UT DS1 spacecraft flew by 19P/Borrelly at the south ecliptic pole
  - Heliocentric distance of 1.36 AU, and Geocentric distance of 1.48 AU
  - The closest approach during the flyby was 2171 km from the comets surface
  - Relative velocity of 16.58 km/sec
- MICAS Images
  - First high-resolution images of a Jupiter-family comet and its surrounding environment
  - Detailed view of the surface of the comet as well as two types of dust features: broad fans and narrow jets that suggest collimation
  - The MICAS observations of the Borrelly jets are likely to provide detailed information on the jet, and a more stringent test of the model because of improved photometry relative to the observations of comet Halley

Overview

- Observational Parameters
  - Long narrow jet pointed toward the sun
  - Located directly on the comet's spin axis
  - Intermediate and Ground-Based images will give a wide range of resolutions and time frames

- Measurements and Constraints from Data
  - Characterize the jet at different distances and directions
  - Use the stereo information from the flyby to construct a 3-D distribution of dust

- Testing the proposed models
  - Do these models work?
  - Can the model be modified using reasonable physical constraints?
  - Can a large number of smaller jets be used produce the same effect?
  - What can the model tell us about non-uniform composition and the comet's evolution?

Research Question

- By studying the Deep Space 1 images of comet 19P/Borrelly, how well can we characterize the collimation that the major jets exhibit?
  - Collimation
    - Narrow jets are highly concentrated flows of dust, which produce a high-density region expanding radially away from the nucleus
    - The gas and dust is decoupled due to the rapid drop in density as gas and dust expand moving out of the nucleus, therefore the dust is allowed to continue in a collimated beam into the vacuum
- If so, can we then replicate the observational data using the proposed models for this cometary mechanism?
  - Details on models

Other Models

- There have been many mechanisms proposed to explain the collimation process, including ones that discuss the topography of the surface of the comet, or theories on trenches, craters, or cavities below the surface.

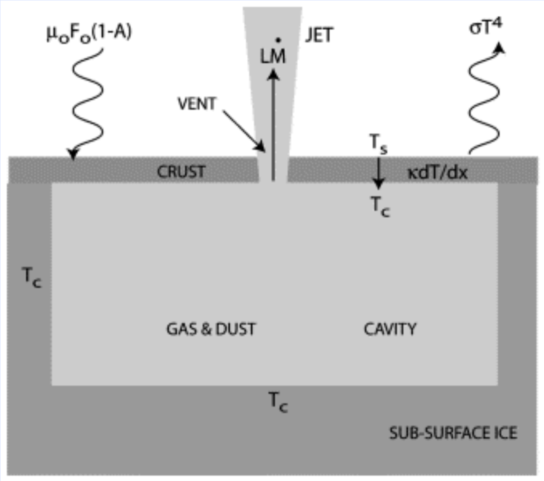
- If the surface material is diffuse allowing gas and dust through a wider area, or if there is a large number of smaller pores, then all vents can contribute to the single jet.

None of the simple models have been extensively tested to determine whether they can easily explain the collimation

Borrelly is the ideal test case because the jet is positioned on the comet's rotation axis

- Brightness is related to density
- Assuming geometrical scattering

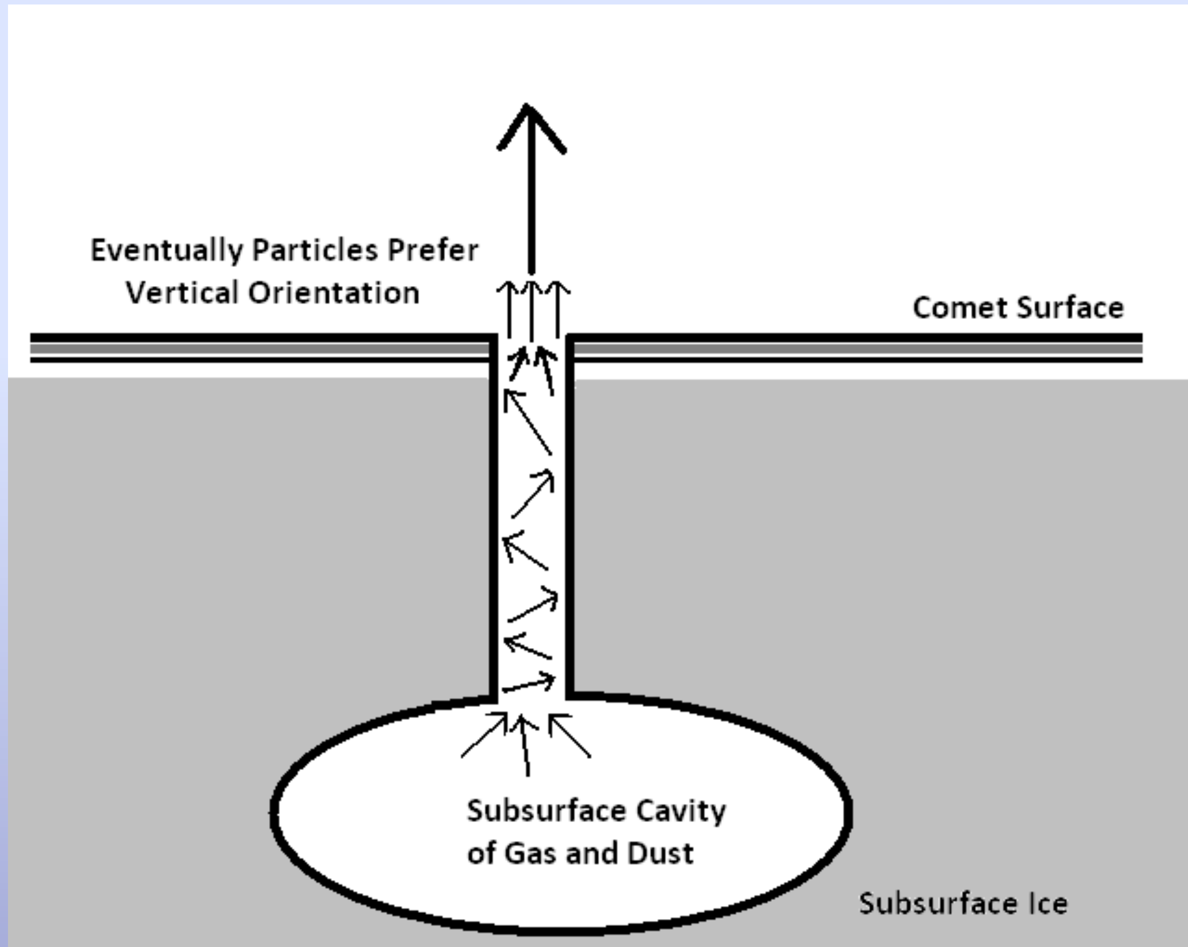
Yelle, 2004 Model



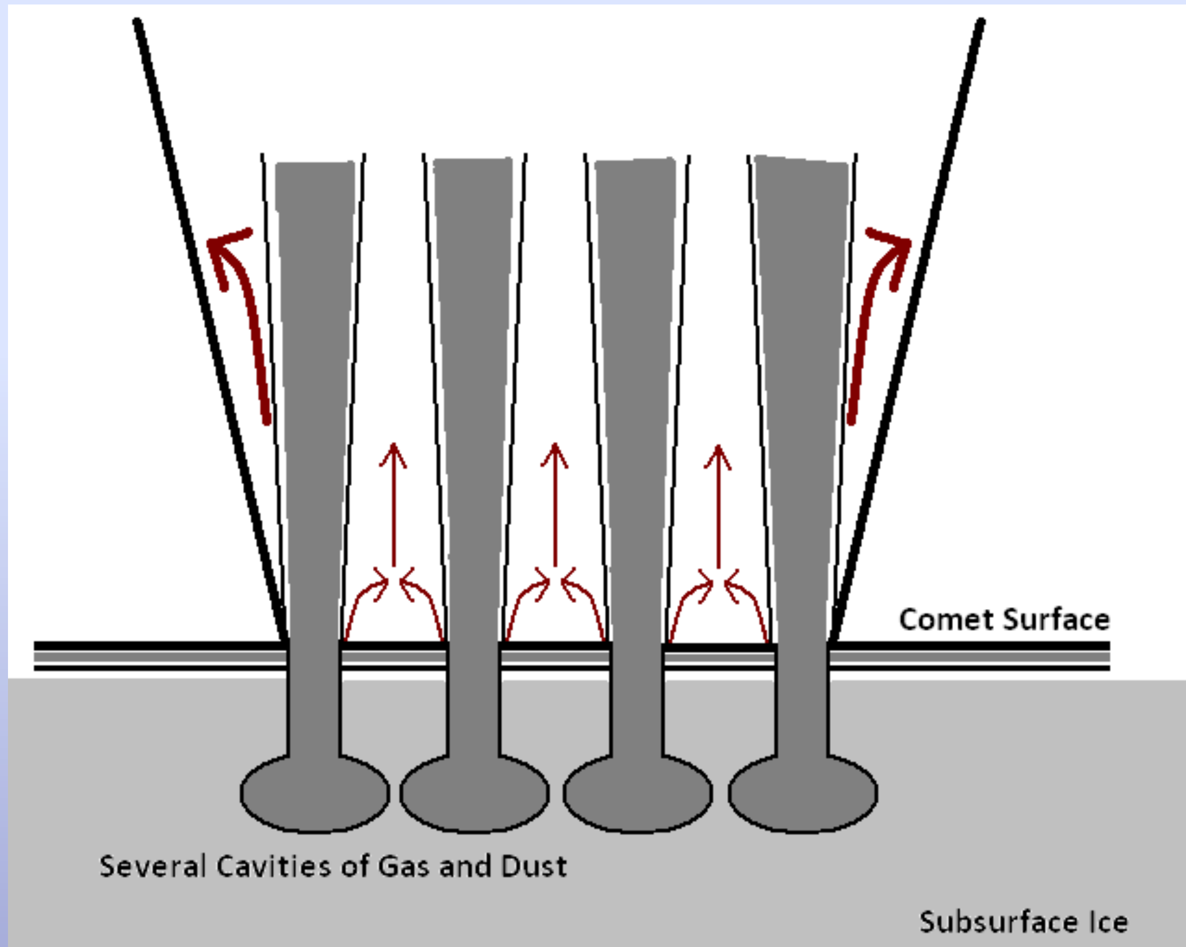
- Solar energy absorbed by the surface is partitioned between re-radiation and conduction to the subsurface. The energy conducted to the subsurface raises the ice temperature and consequently the gas pressure in the cavity. The flux of energy conducted to the subsurface is balanced by the flux of latent heat in the jet. (Yelle, 2004)

- The difference in pressure between the subsurface gases and the vacuum of space causes the gas and dust to be expelled from subsurface cavities and outward.

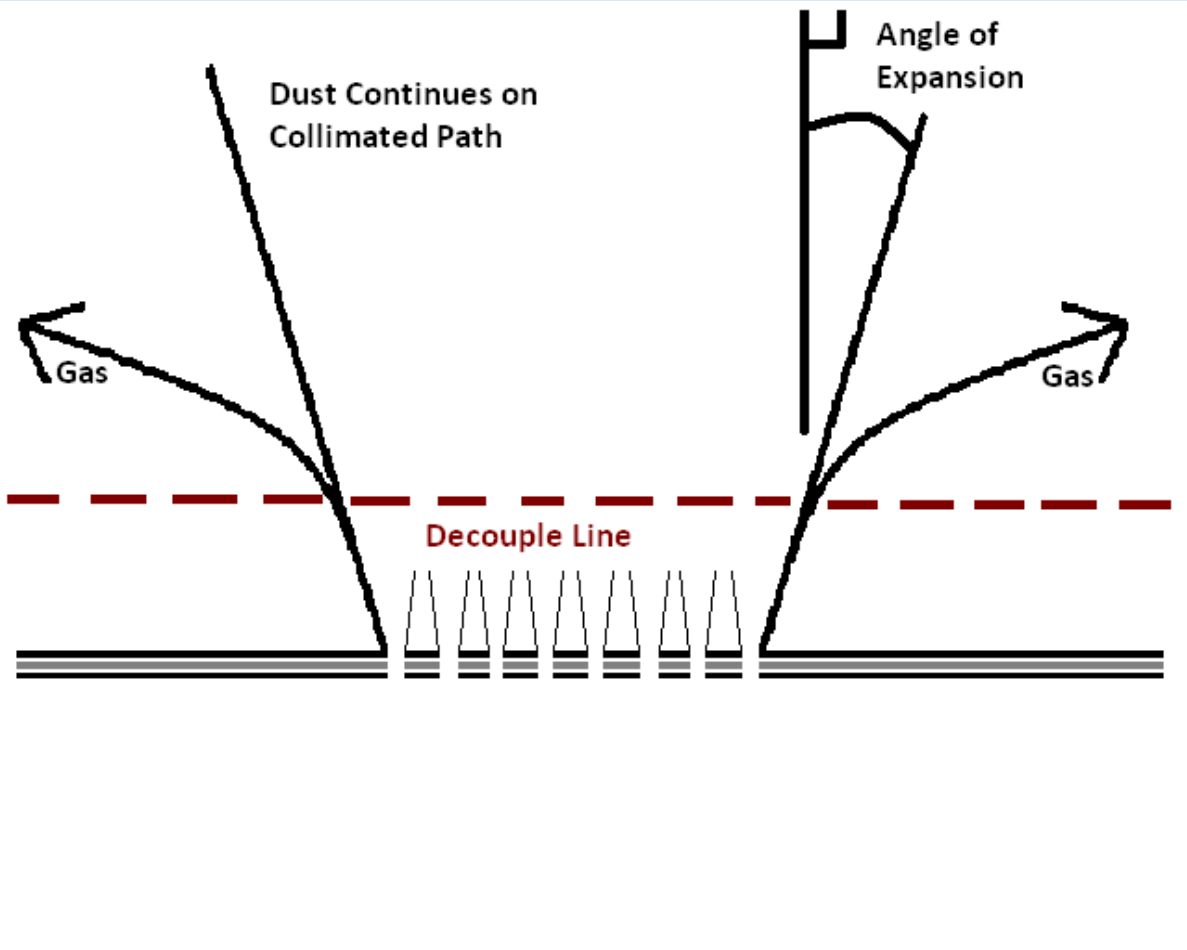
Single Cavity



Several Cavities



Radius of Decoupling



Constraints on the Models

- Observational Parameters
  - Rate and Angle of Radial Expansion of the Dust
    - Although jets are primarily radial, they can show curvature at increasing distances from the nucleus due to rotation of the comet, or exponential expansion
  - Velocity is needed to show decoupling before expansion, and to prove that system is in a steady state – Data from Ground Based Images are under the same conditions as the DS1 images
- Other Constraints
  - The models may require parameters that we will make reasonable physical assumptions for or use data from other scientific studies (to be cited later)

Expected Uncertainties

Current Research Methods

- Interactive Data Language, Linux Operating System
  - DS1/MICAS Uncalibrated VISCCD and SWIR Dataset on the PDSSBN archive website
  - Examine the near_ccd fits files which were taken during the final 10 hours of approach
  - Data will be analyzed using the Interactive Data Language
  - Existing software will be used to create 3-D representation of Jet
- Finding data for the Jet
  - Jet is aligned with the rotation pole, so it is always pointed in the same direction in space, therefore no shape model is necessary
  - Find where the dust particles are due to the intensity of the light that is scattered
  - Search for radial variations that might be indicative of layering in the comet's nucleus

Expected Results

Example Data Graph??

Summary

- Gather Observational Data for the major jet of 19P/Borrelly using the DS1 MICAS Images and Ground-Based Images found at PDSSBN archive website

- Combine with the stereo information from the spacecraft flyby to create a 3-D representation of the jet

- Evaluate the proposed models to reproduce the density distribution of dust found in observations

References

- Yelle, R. V., L. A. Soderblom, J.R. Jokipii. Formation of jets in Comet 19P/Borrelly by subsurface geysers. 2004, Icarus 167, 30.

- Farnham, Tony. Coma Morphology of Jupiter Family Comets. 2008

- Ho, T. M., Thomas, N., et al. Analysis and Interpretation of the Dust Emission of 19P/BORRELLY, 2002, Bulletin of the American Aastronomical Society, 34, 868.

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